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RIVER POLLUTION AND FISHERIES

BY

Dr. H. C. REDEKE

PREFACE

This report on "River Pollution and Fisheries" has been written by order of the International Council for the Exploration of the Sea with the object of giving a summary of the nature of the principal pollutions with which different countries have to deal and the laws and other measures in force for preventing such damage, including the subject of the practical treatment of polluting effluents.

It aims at giving preliminary information to all who wish to learn how these matters stand to-day and I have therefore laid much stress upon compiling the results of recent investigations rather than dwelling too long on such details as are only of a historical interest.

I have confined myself to river pollution *sensu strictiori*, that is to say: the soiling and spoiling of inland waters caused by action of men and thus left out all questions connected with the pollution of sea water and with natural water pollution.

As this report in the first place is intended to supply material which may be useful to fishery-experts I have tried to summarise as fully as possible our actual knowledge of the influence which various polluting matters exert upon fishes. In nearly all textbooks on sewage disposal and trade waste waters this side of the problem is practically left out of view.

I hope that the rather comprehensive bibliography at the end may be of service to those, who wish to go farther into questions which I could touch upon only incidentally.

Finally I wish to express my indebtedness to all those members of the Council and of the Limnological Committee, who gave me valuable help in preparing the last Chapter.

April 15th. 1927.

H. C. Redeke.

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Report on the pollution of rivers and its relation to fisheries

by

Dr. H. C. Redeke — Helder

Introductory remarks

For many years the pollution of rivers by industrial waste products and sewage or sewage effluents has caused more or less serious damage to fisheries. There are several wellknown instances of rivers, where fisheries in consequence of over-pollution have been reduced to very small proportions. Either those rivers have ceased, from source to mouth, to be a fit habitation for certain important species (salmon and trout), or the pollution is more localised, so that in certain parts of the river fish life is practically impossible.

To what extent such a pollution may produce a nuisance or cause disease to human beings is not to be discussed here: I shall confine myself in this report to its bearing on fish and fisheries.

The first two chapters contain a description of the polluting agents together with a summary of the outstanding methods used in connection with the disposal and purification of sewage and industrial wastes. The third chapter is devoted to the influence of river-pollution on fishes and fisheries. In the fourth chapter a short résumé is given of regulations to prevent pollution in various countries. The bibliography at the end of this report contains the titles of the most important papers relating to the subject.

The causes of pollution may be divided into two groups:

I. Sewage and domestic effluents (from towns and villages).

II. Industrial (trade) wastes.

CHAPTER I

Sewage and domestic effluents

In the 5th Report of the Sewage Disposal Commission (1908, p. 11) the following definition is given of sewage: "Sewage generally may be said to consist of a mixture of saline matter in solution and nitrogenous and carbonaceous matter

in solution and suspension together with a certain amount of grit and mineral matters".

The sewage may be either purely domestic or mixed with industrial wastes. The latter is the case in most towns where certain manufactures turn their liquid waste products into the sewers. Their influence will be treated in the next chapter.

"Domestic sewage as it enters the house drains in dry weather consists mainly of dirty water derived from various household operations, containing, amongst other things, faeces, urine, paper, soapsuds, bath water, hair and fibre, soap, matches, candle ends and various other articles; after this mixture has passed into the sewers it often receives drainage from urinals, stables, pigsties, etc.; further it usually becomes mingled with a certain — or rather an uncertain — volume of subsoil water which gains admission to the sewers. If the sewerage system is, what is known as combined (i. e. when all street and roof water enters the sewers), it will also, in dry weather, receive washings from streets when they are watered, containing grit, horse dung, oily and tarry matters. During rainfall, soot, leaves, dust, excreta of birds, etc. will be washed to the sewers from roofs of houses via the house drains and the sewers will also receive from the road gullies organic and inorganic matter washed from backyards, gardens and street surfaces." (Kershaw, 1915, p. 29.)

Although the "strength" of the sewage largely depends on the supply of water, with which it is diluted, it may be said that the chief components always are the same. These components, chiefly consisting of organic and ammoniacal matter, in the course of time are completely, or nearly completely, oxidised through the agency of bacteria. This oxidation requires a varying amount of oxygen, dissolved in the water. Hence in water polluted by sewage the quantity of oxygen is much reduced, and is often less than the amount, that fish normally require for their breathing.

The harm caused to fish (and other aquatic animals) by the influx of domestic sewage into rivers thus mainly consists in the consumption of dissolved oxygen.

This consumption is greatest in the actual neighbourhood of the sewage intake, but as rivers have the power of cleansing themselves (self-purification), at a certain distance below the source of pollution the amount of oxygen will increase and finally will be normal again.

Kolkwitz and Marsson (1908) have distinguished in polluted rivers three zones according to the degree of pollution: a polysaprobe, a mesosaprobe and an oligosaprobe zone, each of which is characterized by its own particular flora and fauna.

The fishes which can still live in each of these zones are the following:

a) polysaprobe zone: no fishes;
b) mesosaprobe zone: carp, crucian carp, tench, barbel, stickleback, etc.
c) oligosaprobe zone: all other freshwater fishes, including salmon and trout.

It will be recognised, that the range of each of these zones and consequently also of the damage done to fisheries, entirely depends on the relation of the total quantity of sewage to the capacity of the river. Small quantities of sewage put into large rivers will do hardly any harm; they sometimes are supposed even to be advantageous as they to a certain extent increase the "fertility" of the water, in the same way as manure on the land. On the other hand large quantities of sewage may cause a vast and serious pollution even in medium rivers.

As is well known, pollution is most dangerous in summer time, when the same volume of sewage as in winter is mixed with a greatly diminished volume of water, that flows less rapidly and consequently is not so thoroughly aerated. The use of oxygen by the various organisms is also much stronger during summer than during winter.

In considering means of purification of the sewage the question thus arises: what degree of purity is required in the circumstances of a river into which the liquid refuse of a town is to be discharged?

The methods of treatment of domestic sewage are very different[1]). They can be brought under four headings viz.:—

1) Dilution.
2) Removal of suspended matter.
3) Decrease of putrescibility.
4) Disinfection.

It is not my intention to give a full account of all methods of purification, that are in use or have been in use nowadays, as many processes still are in a stage of experiment, while others have not proved to be successful. Nor shall I give detailed descriptions of tanks and other apparatus for purification, which are to be found in every technical treatise on sewage disposal. The titles of the most important are given below. I will confine myself to setting forth the principle of each of the above named methods and to discussing their usefulness in relation to fisheries.

1. Dilution

The method of dilution is based upon the self-purifying properties of the rivers, into which the sewage is discharged ("Vorfluter").

In most cases the effluents have varying degrees of purity before reaching the rivers (see below). The (English) Rivers Pollution Committee in 1868 advocated the purification of sewage by land treatment and insisted upon the sewage being purified in that way before discharging. In France Calmette required that no town should discharge effluents that were more polluted than the water derived

[1]) For this section I used chiefly KERSHAW's textbook (KERSHAW 1915) and JAN SMIT's monograph (SMIT 1925).

from the rivers. In later days these rigorous instructions have been dropped, chiefly since the self-purifying properties of rivers have been studied more closely — especially in Germany and America — and at the present time a burdening of the rivers to the uttermost, is generally recognized as the most practical method for complete purification.

Local circumstances however differ widely as regards different towns and rivers. One of the most important factors for purification by dilution is the quantity of water available, usually measured by the capacity of the river i. e. the number of cubic meters of water passing through the river bed per second (mean water). In the following table some characteristic figures are given:

Rhine (Düsseldorf)	2000	m^3/sec.
Elbe (Magdeburg)	500	—
Oder (Stettin)	300	—
Elbe (Dresden)	270	—
Trent (Nottingham)	100	—
Ruhr (Steele)	60	—
Havel (Potsdam)	60	—
Thames (above London)	60	—
Spree (Berlin)	40	—
Mersey and Irwell	10.5	—
Emscher	9.0	—
Aire	2.3	—

These figures and many other details are taken from the recent and important paper by Jan Smit (1925).

Per 1000 inhabitants the German towns as a rule have much more water at their disposal than the English. This accounts for the question of sewage-disposal being much more urgent in England than in Germany.

The dilution in a river may be regarded upon as satisfactory, if it has a capacity of 0.1 m^3/sec. or 8640 m^3 in 24 hours per 1000 inhabitants. The total quantity of sewage per 1000 inhabitants in 24 hours being 100 m^3 on an average this gives a dilution of about 86 times.

As a rule a dilution of sewage effluents with 30 times their volume of water is sufficient to prevent putrefaction, but in some cases a greater dilution is required.

If possible the mixture of sewage effluent and river water should take place in the middle of the river so as to prevent the accumulation of sediments near the shore.

2. Removal of suspended matter

All crude sewages contain suspended matter, from coarse floating solids (faeces, corks, paper) down to microscopic particles. As the coarse elements can hardly be worked up by the self-purifying power of the water, they will form putre-

fying and bad smelling sediments on the river bed and therefore ought to be retained. The removal of this suspended matter by screening in England is usually regarded as a preliminary to facilitate further treatment (see below). "In Germany, where the rivers are for the most part of large volume, screening has been almost brought to a fine art, and it is regarded in many instances as a final process of treatment for the sewage of large towns." (KERSHAW 1915, p. 60—61).

There are several forms of screens, that need not be described here, often combined with so called "grit chambers" whose function is, to remove the heavy particles of grit that are always present in town-sewage and pass through the bars or mesh of the screens.

Even after passing through these grit chambers there remains a large amount of suspended matter in the sewage-liquor that should be removed, before the liquor passes into filters or contact beds. The method of removing these smallest particles of suspended matter is known as "tank treatment". In one form or another the tank-treatment forms an important part of modern sewage purification.

There are three types of tanks:—

a) Sedimentation tanks.
b) Precipitation tanks.
c) Septic tanks.

In the sedimentation tanks the suspended matter is allowed to settle: it falls to the floor of the tank and forms there the so called "sludge" which should be removed periodically.

In the precipitation tanks chemicals are employed to facilitate the settlement of the suspended matter. The chemicals generally in use are lime and alumino-ferric, often used in combination. These tanks are useful when it is desired to produce a tank fluid with a minimum of suspended matter, but the disadvantage is that the volume of sludge is larger and in consequence more difficult to get rid of than in the ordinary sedimentation tanks.

In the septic tank the contents are allowed to become putrid and partially liquefacted, so that the quantity of sludge is reduced.

The septic tanks process deserves a somewhat more detailed treatment. The prototype is the well known "Fosse Mouras" (about 1860). In England CAMERON, in Germany ALEX. MÜLLER have been the promoters of this system that was once believed, to have solved the sludge problem.

The sewage is passed slowly through open or closed tanks, the sludge being left in the tank for a considerable time, to undergo putrefaction and diminution in volume. In the beginning it was generally expected that all organic matter would be digested, that all pathogenic microbes would be destroyed and lastly, that the septic tank liquor would be more amenable to subsequent treatment than other tank liquors. As the digestion of solids and the destruction of bacteria

are much less considerable than originally was held to be the case and as it has been proved that the septic tank liquor was not more easily oxidised by filters than other tank liquors, the septic tank treatment has lost much of its importance and actually is put into practice only in small installations. Sometimes they may be useful for equalising the strength of a variable sewage containing trade refuse.

In a well working septic tank 60—70 per cent. of the suspended matter can be separated; the amount of oxygen which the efluent can take up may be 35 per cent. less than the amount which the sewage takes. On the other hand, the products of decomposition, — ammonia and sulphuretted hydrogen —, increase and counteract the biological processes on the filters more than these are aided by the diminution of the suspended matter.

The "Cultivation tank" (Scott Moncrief) and the "Biolytic tank" (Winslow and Phelps) are special forms of septic tanks.

The "hydrolytic tank" of Travis (1911) is to be regarded as a most important improvement of the old-type septic tank, in so far as it aims at removing the suspended solids automatically from the liquor before putrefaction occurs.

In the Travis tank sedimentation is furthered by the downward projection of a volume of liquid and the removal of finely divided suspended and colloid matter by interposing selfcleansing surfaces in the sewage flow. The deposited sludge is periodically removed. (For details see textbooks).

A modification of this tank is the well known "Imhoff tank" or "Emscher tank", undoubtedly one of the most efficient types up to the present time. For a description I again quote Kershaw (ibid. p. 100—101): "This form of tank, which at first sight bears a strong family resemblance to the Travis tank, appears to have been first installed at Recklinghausen in Germany about 1907 and was the outcome of work by Dr. Imhoff, having for its object the attainment of digestion of sludge in a tank, without allowing the tank liquor itself to become septic, this being effected in a two-storied tank, in the upper portion of which the sewage passes through horizontally in a fresh state, whilst the suspended matter during the passage of the sewage falls through slots in the bottoms of the upper or settling chamber into the lower portion or sludge chamber thus keeping the two processes separate. There is no flow of sewage in the lower, or sludge chamber, and the Imhoff tank thus differs from the Travis tank, in which a certain amount of flow occurs in the lower or sludge chamber. Further, in the Imhoff tank, the slot at the bottom of the settling chamber is overlapped about three inches to prevent gas or sludge rising from the lower to the upper compartments, proper vents for the purpose being provided at the sides of the tank."

Plans and sections of this tank are to be found in all recent textbooks on sewage disposal. Many Imhoff tanks are now in use in Europe and America. Their great advantage is, that the sludge is not disturbed by inflow of sewage and that

the sewage itself is not "infected" by putrid sludge. Nearly 95 per cent. of the suspended matter can be separated and the effluent is then well prepared for further treatment.

Modifications of the Emscher tank are: the Francke tank (1918), the Oms tank (MÜNKER, 1921) and the Erfurter tank (STRASSBURGER, 1923).

3. Decrease of putrescibility

The methods described in the foregoing paragraph all aim at getting rid of the suspended matter of the sewage. With this, however, purification has not come to an end. Even the clearest effluent nearly always contains compounds liable to putrefaction, and a further treatment therefore is necessary unless the river ("Vorfluter") has enough capacity to take and digest the effluent as it comes from the tanks. In Germany and partly in America, authorities feel inclined to make use of the self-purifying properties of the rivers to the extreme; in England and France on the contrary, chiefly because the rivers are much smaller (*vide supra*), the effluent should as a rule be further treated in order to diminish their putrescibility, before they are allowed to reach the public waters.

Land treatment is the oldest form of sewage purification, as it seems to have been employed as far back as in the eighteenth century near Edinburgh. Where the soil and subsoil are of a suitable character and the volume of sewage per acre is not too excessive it produces a high-class effluent. The impurities are finally converted to carbonic acid, nitric acid and water through the agency of bacteria present in the soil.

There are two systems to be distinguished: irrigation and filtration (surface-irrigation and land-filtration). In the former, the sewage is allowed to flow over the land in a thin layer, the area being inclined, in the second the area is led out level or nearly so, with embankments to retain the liquor, that gradually sinks down. In both cases the land thus treated is used for growing crops.

Surface-irrigation is mostly put into practice in England; in other countries the filtration process has been found more suitable and is practised by several towns. For details see textbooks.

A very important improvement of the filtration method is the so called "intermittent filtration" (EDWARD FRANKLAND). Contacts of about 6 hours alternate with long resting intervals of about 18 hours and it has been proved, that by this system 10—12 times the daily quantity of ordinary land-filtration can be treated. (For the theory of absorption cf. DUNBAR, 1912).

The effluents are characterised by a high degree of purity, as the decrease of the oxidability and of the ammonia (albuminoid and other) as a rule amounts to over 90 per cent. Also the number of bacteria is very materially reduced (up to 99 per cent.). The purification in this and other land methods is chiefly due

to the agency of bacteria and other micro-organisms. I may add that, as it is well known nowadays that uncoloured flagellates play an important part in the purification of polluted waters, it is possible, with regard to this remarkable destruction of bacteria, that also in land filtration such flagellates are very essential.

Biological filtration.

a) Contact beds. "Contact beds consist of watertight tanks provided with inlets and outlets for sewage or tank liquor, underdrained and filled with hard durable material, such as clinker, coke, broken stone etc., the size of the material varying according to several factors, such as nature of sewage, character of preliminary process etc." (KERSHAW, ibid. p. 218). The filling should be periodical; automatic gear is often used for filling and emptying. The chief agents, by which the purification is brought about are biological, the fine suspended and colloidal matter forming a cover on the contact material, in which a very characteristic fauna and flora develops.

In the Fifth Report of the Royal Commission of Sewage Disposal (1912) is stated: "Our knowledge of the action of a contact bed is very incomplete, and little is known as to the manner in which the organic substances of sewage are broken down during the first stages of fermentation into carbon dioxide, ammonia etc. The purifying agents seem to be not only bacteria, but also worms, larvae, insects etc. and we can offer no opinion as to the respective amount of work done by each set of agents."

Purification by contact beds is very effective, varying between 60—90 per cent. (single contact) and 90—95 per cent. (double contact). From a bacteriological point of view however the contact bed method is less reliable than land treatment, as the effluent still contains a large number of bacteria.

b) Percolating or continous filters. The liquid to be treated is usually admitted to the filter and passes through and from the filter continously, whilst the supply of air is practically constant.

Purification is furthered very materially by using distributors, by which the liquor is distributed uniformly all over the filter. Revolving distributors are generally used. For this and other types cf. textbooks.

A drawback of the percolating filters is, that sometimes large quantities of suspended matter pass away in the effluent and unless the effluent passes over land before reaching the river ("Vorfluter") some form of settlement or final straining will be necessary. (Birmingham separator tank or other settling basin.) The effluent cleared thus is in France and Germany (Strassbourg, Frankenthal and elsewhere) discharged in fishponds, where it gives rise to an abundant production of lower crustaceae, which serve as food for young fish, especially carp and tench.

c) Activated sludge method. Recently a most important method of sewage treatment has been introduced, known as the "activated sludge" method. This again is chiefly a biological process and is to be compared with filter-treatment, with this difference that the contact material consists of the fine suspended matter itself, whose particles are kept in constant motion by aëration of the liquid. These particles are overgrown by a thin layer of bacteria and protozoa, the living active agents: hence the name "activated sludge".

After a preliminary treatment to remove coarse suspended solids and inorganic material (sand, grit), the liquor is aërated in the presence of activated sludge, either by inflow of air or mechanically; sometimes both methods are combined. Then the sludge is allowed to sink down in a settling tank, from which it is partly removed to the spot where it again comes into contact with fresh sewage. This is known as the "continu" system, which nowadays generally is in use. In the older "discontinu" or "fill and draw" system the arëation and the settling of the activated sludge took place in the same tank. (Fowler, Ardern and Lockett, 1912, Diénert, 1917.)

Activated sludge installations are found in England (Activated sludge Ltd.), France, Holland and America. In Germany they are disliked, chiefly for the great expenses connected with new installations. Recently however Imhoff (1925) has strongly recommended the new system.

New and highly perfect installations are to be found at Manchester, Sheffield, Rotherham and Easton, Bury (Bolton, 1922), Bradford (Garfield, 1922) and elsewhere. For descriptions see bibliography.

Microscopical investigations have shown that the activated sludge consists of an amorphous, gelatinous substance, loaded with an enormous quantity of bacteria and protozoa. The great importance of the latter has been proved by Richards and Sawyer (1922), who found that partial sterilisation by toluol — killing the protozoa and perhaps some of the bacteria — had an unfavourable influence upon the purification processes. Buswell and Long (1923), who more intensively studied the nature of the protozoa, found that they were chiefly infusorians: *Paramaecium* (appearing after 2 days), *Colpidium* (after 3 days), *Vorticella* and *Carchesium* (after 6 days). *Vorticella* and *Carchesium* seem to be the most characteristic (and most effective?) protozoans of the activated sludge.

The results obtained by the activated sludge method seem to be excellent. The effluent is clear, colloids being removed, slightly coloured and not putrescible; there is no unpleasant smell. Dissolved organic matter, organic nitrogen and albuminoid ammonia are highly reduced, from 80—90 per cent. Suspended matter trifling or totally absent.

The mean results (1921—1922) of the installation at Withington (Manchester) are given as an illustration (Smit, ibid. p. 76).

	Sewage (strained)	Effluent	Decrease
Oxygen absorbed in 4 hours	47.5 mg/litre	8.4 mg/litre	82.3 per cent.
Free and bound ammonia	38.2 —	25.9 —	32.2 —
Albuminoid ammonia	9.4 —	1.86 —	80.0 —
Nitrites (NH_3)	—	0.86 —	—
Nitrates	—	4.6 —	—
Absorption dissolved oxygen (Royal Com. Test)	—	14.0 —	—
Suspended matter	123.8 —	7.1 —	94.4 —

In addition it may be mentioned, that the quantity of sludge obtained is very considerable and therefore rather troublesome to dispose with. It has however a great manurial value.

4. Disinfection

Disinfection or sterilisation of sewage-liquors may be looked upon as an additional purification in such cases where the effluent is discharged in rivers, from which water for drinking purposes is drawn.

Although the effluents from sewage farms or artificial filters may be very good from a chemical and physical point of view, they are generally liable to contain large numbers of bacteria of intestinal derivation. If such bacteria are to be destroyed, the effluents must be subjected to some additional treatment.

Lime, chloride of lime, and recently chlorine gas (liquid) are usually employed. In America sodium-hypochlorite ("chloros") is strongly recommended by SIDGWICK and PHELPS, to protect shellfish layings.

As to the influence of sterilisation upon fish I may quote a passage from HOUSTON:

"Careful experiments have been carried out with fish, and the results lead me to conclude that no danger to fish life is to be apprehended, provided the dose of chloros is not greatly in excess of what is actually required for sterilization purposes and the duration of contact is sufficiently long to exhaust most of the active part of the material." (Fifth Report Sewage Disposal Commission App. IV, 1908).

In concluding this chapter we may state that the problem of domestic sewage disposal has on the whole been solved in a very satisfactory manner. The old methods of land treatment, in itself a biological process, have given place to more modern scientific methods of purification, of which the activated sludge process undoubtedly is the most efficacious and should be employed wherever possible.

CHAPTER II

Industrial wastes

The same reasons, which have lead to more or less successful regulations for the treatment of domestic sewage before its being discharged in public waters apply to the waste waters of factories and industrial works (trade wastes). From a standpoint of fisheries the latter are even more important, as they may contain substances which are directly poisonous to fish. On the other hand trade wastes differ from sewage liquors in that they as a rule do not contain pathogenic microbes[1]). Trade wastes are either solids or liquids, but are as a rule in a liquid form. Heaps of chemical refuse however may become sources of pollution through the agency of rainwater.

Unfortunately our knowledge of how to treat trade wastes in order to prevent them from doing harm to fisheries is far more incomplete than it is in the case of domestic sewage.

As a full treatment of all the wastes comprised in this subject lies beyond the scope of this report, I may confine myself to an enumeration of the most important industries producing wastes, which have been or are more or less detrimental to fisheries and to a short indication of how to dispose of them. For more detailed information I may refer to the textbooks of Naylor (1902), Wilson and Calvert (1913), Calmette (1907) and Pritzkow (1914), to the 6th and 9th Report of the Royal Commission on Sewage Disposal and to Jan Smit's recent summary of the subject (1925).

It may be of importance to mention beforehand, that in many cases trade liquors are admitted to town sewers. By this they are mixed up with domestic sewage and can be treated in the ordinary purification plant, provided that their relative quantity is not too great. This dilution is often very beneficial, as the sewage will neutralize acid agents, which may be contained in the trade liquors or afford substances, which are necessary for biological processes and may be absent in the latter.

In most cases however the trade waste waters are in a more or less purified state discharged directly into the rivers.

In describing the processes from which the waste waters arise and the methods of purification which have been adopted it seems advisable to divide the subject into three paragraphs, according to the nature of the chief constituents of the effluents. I therefore will treat separately:—

1) such wastes as are injurious chiefly owing to the presence of organic matter.
2) wastes which are injurious owing to the presence partly of organic, partly of inorganic matters.
3) wastes which are injurious chiefly owing to the presence of inorganic matters.

[1]) Waste liquors from tanneries and fellmongers' yards may contain spores and bacilli of anthrax.

The words "organic" and "inorganic" are here used in a biological, not in a chemical sense. Organic polluting matter is formed by the decomposition of parts of organisms in contradistinction to the non-living minerals and other chemical compounds, although many of the last named are "organic" compounds in a chemical sense.

In the following I have chiefly borrowed from WILSON and CALVERT'S textbook and JAN SMIT'S excellent monograph.

1. Injurious chiefly owing to the presence of organic matters

Beet-sugar factories produce very large quantities of different waste-waters, which are highly polluting in character, containing large amounts of vegetable organic matters in solution and suspension. The latter (earth, stones, "tailings"), are removed by filtration or settlement in tanks. The best method for purification of the remaining liquor is land-treatment, but it is very expensive as it involves a large area. Putrescibility is decreased by fermentation in large tanks (Stenzel-method). The waste water, to which yeast is added, is slowly carried through fermentation tanks and afterwards conducted to settling tanks, where the suspended matters are deposited. The deposits are mixed with pulp, pressed, dried and used as food for cattle. As to the food value of the refuse opinions diverge, but the effluent is said to be good.

Other methods consist in diminishing the quantity of waste water and using it again. The most noteworthy is the so called "Stephen's Brühverfahren", which was first put into practice at Stendal. The beets after cutting are made into an extract in 6—7 times their volume of nearly boiling water and are afterwards pressed. This method is more simple than the diffusion process and produces less waste water but also less sugar.

In Holland KESSENER and SÖHNGEN invented a new system for treating the waste water. This is made alkaline, strained and again used for several purposes (vide JAN SMIT, ibid. p. 119).

Potato flour and starch manufacture. These wastes are highly putrescent and very similar to the foregoing. Land treatment is sometimes adopted. Septic tank treatment after lime precipitation, followed by a treatment in continuous (percolating) filters have given satisfactory results. The bad conditions prevailing in most waters of the northern provinces of the Netherlands however render it doubtful, whether the present methods of purification are satisfactorily efficacious.

Dairy industry. The waste liquors are chiefly washing and rinsing water, fats, albuminous compounds and other putrescible substances. Lime precipitation, followed by septic tanks and percolating filters, is effective. Fat separation is very important in order that the filters may function satisfactorily. A concise

description of the "methods of disposal of liquid waste from the handling of milk in the manufacture of milk products in Holland" is recently given in "River Pollution and Fisheries" (1926), p. 18 seq.

Brewing and distilling. From these industries very polluting waste liquors are derived. The refuse contains many suspended solids, much dissolved organic matter and in addition many living ferments and moulds, so that it decomposes very quickly. Brewery wastes very soon decompose and become acid, the acidity being caused mainly by the formation of lactic acid. As in the instances just mentioned land treatment or continuous filters give the best results. Mixing with domestic sewage is advisable as the latter may neutralize the liquor and promote purification.

Slaughtering. Large quantities of waste water containing animal organic matter and consequently extremely putrescent are produced in modern industries. Blood should never be discharged along with the refuse water, as it is valuable either as a food or as a manure. Straining followed by removal of grease may make the effluent fit for treatment in sewage plants. Otherwise chemical precipitation with alumino-ferric (no lime!) and biological filtration is indicated. In some abattoirs and potted meat industries septic tanks are used followed by continuous filters which give satisfactory results. In Chicago the activated sludge process is employed.

Fellmongers' yards. The liquid wastes produced by a fellmonger are as a rule not very great in volume, but they are troublesome when discharged into small sewers by reason of the silting up in the sewers caused by the lime employed to loosen the wool and fibre. These liquors are amenable to biological treatment and may be dealt with by mixing in settling tanks, followed by deep percolating filters or land-filtration.

Flax retting. It is well known, that in many countries the retting of flax is effected by the moist method. The plants are soaked in water and undergo there a process of fermentation caused by specific bacteria. This fermentation is accompanied by the solution of much organic matter, producing a very polluting liquid. Disposal of the refuse by irrigation upon land is effective and advisable as it has valuable manurial properties.

The manufactures mentioned in this paragraph all have in common that they produce large quantities of waste water of a highly polluting character which will seriously reduce the natural amount of oxygen in the waters and therefore must be purified before discharging. Land treatment could give satisfactory results, but is in most cases too expensive. If dilution is sufficient, so that the effluents are not more polluting in character than ordinary sewage, they may be drained into town sewers. Septic tanks and continuous filters have proved of use. But after all we may say that the disposal of this kind of organic effluent causes still a lot of trouble. Future researches and especially careful studies of the biochemical

and biological processes during fermentation and decomposition (mineralizing) of the organic matter are needed and may lead to the discovery of satisfactory processes of treatment which are at the same time efficacious and economically practical.

2. Injurious owing to the presence partly of organic, partly of inorganic matters

Leather trades. The organic polluting substances contained in the waste waters of these industries, are blood, "fleshings" (pieces of connective tissue) and other animal matters, originating from the soaking and scraping of the skins. The inorganic matters consist of chemicals, used in the modern tanning processes: lime, sulphate of soda, arsenic compounds or chromates. It is advisable to keep the various wastes separate. The lime liquors may be used for precipitation of the chromate containing liquors, but it will be found advantageous to use additional precipitants. Alkaline and acid waters may be mixed in order to neutralize each other. After precipitation of the lime and settling of the tanning liquid the effluents can be further purified by careful irrigation. The refuse can also be rendered non-putrescible by treatment in double contact beds (Dunbar).

Cellulose manufactures. The raw material used in this trade, (wood, pulp, rags of linen and cotton, for paper also esparto grass, straw etc.), is of vegetable origin and is nowadays treated by bisulphite of lime. The refuse in combination with large quantities of cleansing and swilling waters is known as "Sulfitlauge" and has caused considerable nuisance. Dilution is as a rule impracticable in view of the large quantity of water that is needed (3000 : 1). Land treatment is only effective after neutralizing, precipitation, dilution and addition of domestic sewages. The process now in vogue is fermentation, by which alcohol is produced (Hägglund). The resulting effluent is however still extremely putrescible and needs further treatment either by irrigation or dilution. Recently the dried sludge has been used as manure (Bokorny) or fuel, "Sulfitkohle" (Strehlenert).

If the cellulose is used in the paper trade the refuse contains moreover the discharges of various reagents used in the processes of manufacture such as bleaching, colouring, sizing and filling. The resulting refuse has therefore a very complex character, varying with the different kinds of paper which are made. A very noxious effluent is produced by the straw-board manufacture. Septic tank treatment is recommended, and precipitation by iron salts and lime followed by intermittent filtration may yield satisfactory results.

Textile trades. This section comprises "all the processes by means of which fibrous materials either of animal or vegetable origin are made into woven fabrics. The most important of these raw materials are cotton, wool, silk, flax, hemp and jute and the processes which they undergo yield waste waters which for the most part fall into two categories, the first comprising the liquids which

result from the cleansing and preparation of the materials, the second those coming from the manufacturing and finishing processes. Refuse of the first kind, such as that from wool washing, silk boiling and flax retting contains much organic matter, which has been extracted from the materials themselves, whereas the other kind of refuse owes its polluting character chiefly to the various reagents used such, for instance, as oil, soap, fuller's earth and dyewares" (WILSON and CALVERT, ibid. p. 96).

The refuse of wool washing is a very putrescible strongly alkaline liquor which should not be admitted into sewers without being purified. By treatment with sulphuric acid fatty acids are precipitated which yield the grease used for the manufacture of lanoline. The remaining effluent is neutralized and after precipitation of the suspended matter purified by biological methods.

The waste liquors discharged from the cotton-bleaching processes are chiefly diluted alkaline and acid fluids and solutions of chloride of lime. The first two can be prevented from doing harm by being mixed together, the whole being afterwards purified on contact beds, possibly after mixing with domestic sewages and precipitation with alumino-ferric.

The dyeing processes yield refuses, which do not vary greatly with the nature of the material. Therefore they are in all cases amenable to similar methods of purification. For the most part colouring matters consist of highly soluble derivatives of coal tar. The goods absorb most of the dye so that the waste water as a rule contains only little of it. On the other hand it contains sometimes considerable quantities of salts and mordanting materials. Dyes containing sulphur may give rise to the development of sulphuretted hydrogen. Coloration of the rivers and bad smell are often very troublesome, but some of the coal tar dyes are inoffensive to living organisms. Precipitation followed by biological treatment, especially after mixing with sewage, is used here too.

Glue, size and glycerine manufacture. The waste waters contain besides organic matters phosphates in rather large quantities, extracted from the bones by treatment with diluted hydrochloric acid. This is neutralized by lime and the effluent after sedimentation is easily amenable to biological purification and may be discharged into sewers or directly into a river of sufficient capacity.

The waste liquors of this section have in common, that they are of a highly putrescible character and in this respect are of much the same type as those mentioned in the foregoing paragraph. They are, therefore, in the first place noxious owing to their great power of decreasing the amount of oxygen of the waters into which they are discharged. Besides these organic matters they contain however various agents of an inorganic character which may act as poisons and in different ways may be directly detrimental to fishes and other organisms.

3. Injurious chiefly owing to the presence of inorganic matters

Coal trade. There are many operations in this industry which yield waste waters. Some of these are harmless, although they are more or less saline, such as pitwater and silting water. Coal washing, i.e. the separation of the coal from its impurities by means of agitation in water, produces dirty water containing large amounts of fine coal in suspension. In order to prevent the formation of shallows the effluent from the washers have to pass settling tanks or ponds before they are allowed to flow into a river.

The recovering of by-products in gasworks, coke ovens, blast furnaces etc. produces various refuses which are highly injurious. These "gas-liquors" contain aromatic carbohydrates, ammonia and tar. The ammonia is recovered by distillation with lime and passed into strong sulphuric acid in a "saturator". The hot vapors which pass from the still through the acid are cooled and condensed into a liquid which is known as "devil water". It is very poisonous by its content of cyanic compounds, and is sometimes discharged as refuse (Wilson and Calvert, ibid. p. 28). The bulk of the refuse, however, comes from the still, being the spent gas liquor after the ammonia has been driven off along with calcium carbonate and various dissolved compounds of lime (rhodanic, phenolic etc.) and tarry matters. After clarification in tanks a red brown effluent of an extremely complex composition is left. It has a very offensive smell and contains large amounts of noxious compounds (vide chap. III). The great capacity of this refuse for absorbing oxygen is very detrimental to small rivers by preventing self-purification.

The purification of this refuse is a problem difficult to solve and until now it has not been solved in a satisfactory way. Fowler's method (strong dilution followed by treatment on continuous filters) gives good results, but is very expensive. Phenol and other compounds are oxidised by a specific micro-organism and the quantity of oxygen absorbed by the effluent is largely decreased. For other methods of purification vide Wilson and Calvert, ibid. p. 33 seq. and Prüss (1925).

Metal works. In all these industries, such as galvanising, tinplating, wire drawing, copperas manufacture etc., metals (especially copper and iron) are cleansed before further treatment by being dipped into a "pickle" of diluted hydrochloric or sulphuric acid. Afterwards the metals are washed with water. Both the pickle and the wash-water contain large amounts of oxides in suspension and chlorides or sulphates in solution, together with free acids. To render these kinds of waste fit for discharging into a stream, lime must be added to neutralize the acidity. Copper may be recovered by adding iron. Effluents containing iron are amenable to further treatment along with domestic sewage.

Artificial silk trade. The waste waters contain chiefly chemicals such as alkali, sulphuretted ammonia and sulphuretted hydrogen. They have a very offensive smell and attack iron and concrete. Purification of these effluents seems as yet not to have been practised.

Working of salt deposits. The manufacture of potassium-salts from deposits ("Abraumsalze") in the valleys of the Elbe and the Weser yields an effluent, which has caused great trouble by being discharged into these rivers and their tributaries. The oversalting of the water is chiefly due to the refuse of the manufacture of chloride of potassium from carnallite and the wash water of the kieserite which contains a large amount of chloride of soda. The amount of chlorine of the river is increased, which renders the water unfit for domestic purposes (drinking water), as is also its hardness which is troublesome for various trades. Both kinds of pollutions are, however, to a certain extent inevitable, as there is no other method of working up the deposits. The works therefore are controlled so as to prevent overpollution and are bound to give pecuniary compensation in the case of serious damage. Moreover it seems that the self-purifying power of the rivers is not diminished even by a hardness of 110° (German degrees) and 1200 mg. chlorine per litre.

Ore washing, China clay washing and grading. The water coming from these washing operations carries with it large quantities of sand and mud. In some cases the solids are so finely divided that they take a long time to settle, which can be furthered by adding small amounts of lime in the water. After treatment in settling tanks the effluent can generally be discharged into the river without producing serious effects.

The waste waters mentioned in this paragraph have in common, that they contain polluting substances which are esclusively or chiefly of an inorganic character. They may act either as poisons for fish and other living beings (acids and other chemicals) or have a detrimental effect in absorbing oxygen, thus preventing self-purification, or may render the water impure by salts or mud, without directly affecting the fish. It has not yet been possible to purify all these wastes to a satisfactory degree and we find amongst them those which are most dangerous to fisheries. (Vide next chapter.)

Resuming we may say that the methods of purification of trade wastes are much less elaborated than those for the disposal of domestic sewages. It must however be borne in mind, that the diversity of the first named is much greater than that of the last and that special problems, which are continually presenting themselves, must be solved by the adoption of special methods. On the other hand a certain lack of interest on the part of the manufacturers can not be denied and sometimes, although there is a way, there is no will.

In devising the scheme for purification best suited to any individual case the following principles are of importance:—

1° The plant which is adopted for the purification of industrial refuse should be of a variable kind so as to meet eventual modifications of the manufacturing processes which are attended by alterations of the quantity or the quality of the waste water.

2° Different kinds of waste water should be kept distinct, because it is as a rule much easier to dispose of small quantities of a strongly polluting liquor than of large quantities of a less objectionable character which nevertheless are to be purified.

3° Where trade liquors are admitted to town sewers it is to be borne in mind that they as a rule are more concentrated than domestic effluents. Consequently the methods of purification of the last mentioned have accordingly to be modified. They should be allowed to pass from a tank uniformly throughout the 24 hours or at all events the discharge should be spread over as long a period as practicable.

4° Some kinds of industrial wastes containing organic matters have to be treated before being discharged into town sewers. The activated sludge method should be employed where possible.

5° Waste waters containing large quantities of carbohydrates (beet-sugar factories, starch manufacture), involving special fermentation processes, should not be admitted into town sewers. Here contact beds give better results than continuous filtration.

6° Some wastes (coal trade, metal works, artificial silk industry) can never be purified along with domestic sewage but require special treatment. The variable character of these liquors renders it practically impossible, to establish norms, with which the effluents of these trades should be in accordance before they are allowed to be poured into public waters.

CHAPTER III

Effects of polluted water upon fish life

The problems connected with the study of the effect of water pollution upon fish life are very complicated and at the present time still far from their final solution. The effect depends not only on the composition of the polluting effluents, but also on the nature of the water into which they are discharged and to a great extent also on the reactions of the fish living in it. In most cases it is also essential to know, when the pollutions are most concentrated, whether polluting substances cover the bottom and make conditions unfavourable for the hatching of eggs and whether they destroy plants and animals, upon which fish usually feed.

In summarizing the information I could obtain as to the actual or pretended damage caused by water pollution on fisheries it seems advisable to treat separately:

1) such polluting agents as act directly upon fishes;
2) the action of agents upon the medium in which fish are living;
3) the influence of river pollution upon fisheries.

As the information on these questions, especially on the killing of fish by injurious effluents, is very extensive and scattered through textbooks and reports, scientific treatises and newspapers, I must confine myself in this section to a general account of results and for more detailed information refer to the bibliography at the end of this report. Very comprehensive reports on the subject are published by WEIGELT (1900), VOLK (1903, 1908, Elbe), HENTSCHEL (1917, Elbe), STEINMANN and SURBECK (1918, Switzerland), RICHARDSON (1921, Illinois river). A useful account on Purification of Fishwaters has been recently published by WUNDSCH (1926).

1. Direct influence of polluting agents upon fishes

The various constituents of sewages and trade wastes, which act directly upon fishes, belong chiefly to the compounds which may be denoted briefly as "poisons". They are present in the waste waters of most of the industries mentioned in the last paragraph of the foregoing chapter.

It has been known for a long time that various chemicals such as copper and iron salts, caustic and carbonate alkali etc. are exceedingly injurious to fishlife.

WEIGELT (1880, 1881, 1885) was one of the first who investigated the noxiousness of a great number of town sewages and industrial wastes. His results were partly checked by KÖNIG and HASELHOFF (1897).

Although these papers contain abundant of data the investigations were made from a chemical, rather than from a biological standpoint. The lack of a sufficient supply of oxygen in the aquaria rendered the experiments open to criticism. This was admitted by WEIGELT himself in a later paper (1900)[1]).

HOFER (1899) seems to have been the first who systematically aërated the water in his experimental tanks. He found that phenol was highly poisonous to fishes, paralyzing the nervous system.

KUPZIS (1902) gives an account of the poisons contained in naphtha, one of the distillation products of petroleum, which caused a lot of trouble in the Volga and other Russian rivers. The naphtha was transported by wooden barges from which considerable quantities leaked through into the surrounding water. He found that the actual poison contained in naphtha was naphthene acid and tried its effect on frogs, crayfish and on not less than 25 different species of fish.

His most important conclusions (ibid. p. 166) are:—

1) All kinds of raw naphtha, masout, solar oil, petroleum ether, benzene and ligroin contain substances, which are poisonous to fish.

[1]) In his own words (ibid. p. 113): "Die obengenannten Versuchsansteller einschliesslich des Verfassers unternahmen die Versuche mehr vom Standpunkt des Chemikers, ohne den biologischen Anforderungen der Versuchstiere völlig ausreichend Rechnung zu tragen. Auf Grund dieses Mangels sind die genannten Versuche mit einer gewissen Vorsicht auf zu fassen".

2) Petroleum, if well purified, and other similar products are free of poisonous constituents but they become poisonous after being exposed to air and sun.
3) The chief poisoning constituents of naphtha are the naphthene acids.
4) Their poisonous effect depends on the quantity of the poison in solution, which is influenced by the salts in the water. The acids dissolve only, if the water contains carbonates of lime and magnesium. Their solubility is however reduced by chlorides if present in large quantities as in seawater.
5) Naphthene acid proved to be lethal even in such weak solutions as 1:50,000—1:333,000. The size of the fish is of no great importance but certain species, as herring, sturgeon, perch-pike and *Silurus* are more sensitive than cyprinids, eel, goby and lampern. Symptoms indicate chronic poisoning.
6) In order to prevent pollution by naphthenes it is desirable to find some technical use for these acids. They can be very well employed for disinfecting purposes as they have excellent antiseptic qualities.

See also Seydel (1914) on mineral oils.

Pigorini (1907) deals with the toxicity of silver salts. He found that the resistance of fishes against solutions of these salts increases with the decrease in importance of the rôle which the integument plays as a respiratory organ.

Hein (1908), one of Hofer's assistants, investigated the toxicity of coal tar. His results show, that coal tar as such is fatal to fishes (small trouts) even in very weak solutions (1 : 80,000). It acts as a specific nervous poison, affecting chiefly the respiratory functions by causing nervous contractions of the branchial muscles resulting in asphyxia, without injuring the branchial epithelium. Of all species of fishes the three-spined Stickleback (*Gasterosteus aculeatus*) proved to be by far the most resistant and again lower animals were more resistant than fishes.

Reuss (1909), another of Hofer's assistants, showed that carbondioxide acted on fishes in the same way as on higher vertebrates causing dyspnoea by intoxication.

Thienemann's (1911) results show that certain coal tar dyes (Viktoria blau, Methylviolet, Methylviolet B. B. extra, Kohlschwarz B.T. and Diamantgrün B) are extremely poisonous to lower animals and fish, killing them after 12 hours even in such weak solutions as 1 : 100,000, while other dyes were less noxious.

A valuable contribution to our knowledge of the fatal action of metallic compounds on fishes has been given by Léger (1912), who investigated the noxiousness of wastes from several metal cleansing works ("usines de décapage de métaux") in France.

He experimented with small trouts (brook trouts and rainbow-trouts) and minnows (*Phoxinus laevis*). The latter species is said to be the most sensitive of all common European cyprinids, but the trouts proved to be much more sensitive and are perhaps the best objects for investigations on the influence of polluting matters on fish.

For a large number of substances LÉGER determined 1) what quantity could be supported by the fishes for one hour without doing harm ("dilution limite" or "dose maxima supportable sans danger") and 2) what quantity would certainly kill the fishes within one hour ("dose minima sûrement dangereuse ou mortelle"). The following table is compiled from LÉGER's figures and shows the doses either harmless or fatal for the compounds investigated not only for solutions in pure water (distilled and aërated), A, but also for a natural water containing a considerable amount of carbonate of lime[1]), B.

Substances	1 Permissible maximum per mille A	1 Permissible maximum per mille B	2 Fatal minimum per mille A	2 Fatal minimum per mille B
Sulphuric acid H_2SO_4 trouts	0.03	0.15	0.05	0.30
Sulphuric acid H_2SO_4 minnows	0.02	0.15	0.04	0.30
Chloric acid HCl trouts	0.003	0.05	0.005	0.20
Chloric acid HCl minnows	0.003	0.10		
Sulphate of copper $CuSO_4$ trouts	0.0025	0.05	0.025	0.10
Sulphate of copper $CuSO_4$ minnows	0.005	0.20	0.050	0.50
Ferric sulphate $Fe_2(SO_4)_3$ trouts and minnows	0.25	0.25	1.0	1.0
Ferrous sulphate $FeSO_4$ trouts	0.30	0.25	4.0	1.0
Ferrous sulphate $FeSO_4$ minnows	0.30	0.50[2])	4.0	2.0
Sulphate of zinc $ZnSO_4$ trouts	0.25	0.30	0.50	0.50
Sulphate of zinc $ZnSO_4$ minnows	0.50	1.0	2.0	4.0
Sulphate of aluminium $Al_2(SO_4)_3$ trouts and minnows	0.70	1.0	2.0	3.0
Sulphate of lime $Ca\,So_4$	inoffensive even in saturated solutions			
Ferric chloride Fe_2Cl_6 trouts and minnows	0.25	0.25	0.50	0.50
Ferrous chloride $Fe\,Cl_2$ trouts	0.50	0.30	1.0	0.50
Ferrous chloride $Fe\,Cl_2$ minnows		0.50		1.0
Chloride of lime $CaCl_2$ trouts and minnows	10.0		30.0	
Chloride of zinc $ZnCl_2$ trouts	0.10	0.25	0.20	0.50
Chloride of zinc $ZnCl_2$ minnows	0.10	0.50	0.20	1.0

These results show plainly how essential it is to know the nature of the water with which experiments are made.

HAEMPEL (1915) carried out several experiments on the injuriousness of sulphuric acid both with fishes (trout, char, carp) and invertebrates. He found that the acid chiefly affected the skin and the gills and that in the fishes dyspnoea occurred even in such weak solutions as 24 mgrs. per litre. He determined the "fatal minimum" in ordinary (lime containing) water as being about 200 mgrs., a quantity corresponding fairly well with LÉGER's figure (300 mgrs.). The invertebrates proved to be much more sensitive. It may be not without interest to note,

[1]) This water from Rochefort contained about 157 mgrs. calcium carbonate per litre.

[2]) Probably too high (cf. LÉGER l. c. p. 59).

that HAEMPEL found a very remarkable difference between the power of resistance of fishes in warm and in cold water, it being much greater in the latter. The author ascribes this to the fact, that fishes in cold water can neutralize (probably by the lime of their scales) more of the acid than in warm water.

SEEBERGER (1921) studied the toxicity of damson-distilleries refuses ("Zwetschenbrennrückstände"). He experimented with common trout and found a solution of 30 per cent. to be fatal in somewhat less than one hour (55 minutes). Of the constituents of the refuse cyanic acid in solutions down to 0.000625 per mille proved to be very toxic to barbels (*Barbus*), the larger ones being however more sensitive than the smaller. Cyankalium was less harmful, a 0.01 per mille solution being endured by trout and barbel. The chief agent of these refuses, however, is amylalcohol. A 5 per mille solution killed middle-sized perches ("Egli") in 7 minutes.

Other recent investigations (SHELFORD 1917, WELLS 1918, SURBECK and STEINMANN 1920 & 1922) have shown, that nearly all the products of the distillation of coal are very toxic to fishes, some of the most toxic being those which are commonly regarded as insoluble in water. They are in solution in the water used in washing the gas in the manufacture of illuminating gas and in the waste water of numerous other industries such as the manufacture of dyes, pharmaceutic products, explosives, etc. and are often introduced in waterways.

SHELFORD (1917, p.p. 395—396) gives a table showing the relative toxicity of various products associated with the manufacture of coal gas. The toxicities are based on the amount of the substance required to kill in one hour a small sunfish (*Lepomis humilis*) weighing 4—6 grams. In the following table I have rearranged his figures according to their relative toxicity given in parts per million.

Substances			Parts per million
Phenanthrene	$C_{14}H_{10}$	Solid	1—2
Naphthalene	$C_{10}H_8$	—	4—5
Hydrogen sulphide	H_2S	Gas	5
Ammonia	NH_3	—	7—8
Acetone	C_3H_6O	Liquid	14—15
Sulphur dioxide	SO_2	Gas	16—19
Ethylene	C_2H_4	—	22—25
Thiophene	C_4H_4S	Liquid	27
Benzene	C_6H_6	—	35—37
Xylene	C_8H_{10}	—	47—48
Quinoline	C_9H_7N	—	52—56
Orthocresol	C_7H_8O	Solid	55—65
Toluene	C_7H_8	Liquid	61—65
Isoquinoline	C_9H_7N	—	65
Phenol	C_6H_6O	Solid	70—75
Carbon monoxyde	CO	Gas	75
Paracresol	C_7H_8O	Solid	80—90
Carbon bisulphide	CS_2	Liquid	100—127

Substances			Parts per million
Ammonium ferrocyanide	$(NH_4)_4Fe(CN)_6$	Solid	150—200
Ammonium sulphocyanate	$(NH_4)NCS$	—	280—300
Ammonium sulphate	$(NH_4)_3SO_4$	—	420—500
Benzoic acid	$C_7H_6O_2$	—	550—570
Ammonium carbonate	$(NH_4)_3CO_3$	—	600—800
Amylene	C_5H_{10}	Liquid	655—693
Ammonium chloride	NH_4Cl	Solid	700—800
Aniline	C_6H_7N	Liquid	1020—1122
Pyridine	C_5H_5N	—	1477—1576

Besides the above named a few other compounds were studied which proved however to be either not or only slightly toxic. Among these was methane (CH_4), a gas which is very often found in nature rising from pools of stagnant water in marshy districts. No toxic effects on fishes were noted, except in the case of a single specimen of *Labidesthes sicculus*.

Turning back to SHELFORD's figures, we see that some of the constituents of the waste waters of gasworks are extremely poisonous to fish. Among these phenantrene, naphthalene and hydrogen sulphide stand as the first, causing death in even such weak concentrations as 1—5 per million. But other common constituents of trade waste liquors such as ammonia and sulphur dioxide, are hardly less noxious. Very remarkable is also the high toxicity of xylene, toluene and benzene, all occurring in coal tar, the last of which is the most toxic to fishes.

The toxicity of these compounds varies, however, for different fishes. Some fishes are more resistant to a given poison than others. Certain fishes are for all kinds of poison more sensitive than others. I cite from SHELFORD's paper (1918) the following table indicating the relative resistance of a very sensitive minnow (arbitrarily taken to be unity), some other North-American game-fishes and the goldfish.

Species of fish	Relative resistance
Labidesthes sicculus (Brook silverside)	1
Moxostoma aureolum (Red-horse)	2.3
Catostomus commersoni (Common sucker)	2.4
Micropterus dolomieu (Small-mouthed black bass)	5
Micropterus salmoides (Large-mouthed black bass)	6
Pomoxis annularis (White crappie)	8
Pomoxis sparoides (Black crappie, Calico bass)	8
Ambloplites rupestris (Rock bass)	10
Perca flavescens (Yellow or American perch)	10
Lepomis humilis (Orange-spotted sunfish)	12
Carassius carassius (Goldfish or Crucian carp)	12
Lepomis cyanellus (Blue-spotted sunfish)	15
Ameiurus melas (Black bullhead)	45

Shelford found that in the majority of compounds studied the largest fishes survived longest, so the effect of contamination is greatest in connection with the younger stages.

He further showed (p. 408) "that fishes are as a rule indefinite or positive to the substances which are not regularly encountered in their environments. In other words they swim into the poisonous solution without detecting it and turning back as they do in the case of low oxygen and much carbon dioxide. They may go directly into it, without noticing it, and after being for a brief time in the solution they will generally avoid the pure water which is identical with that in which they have been living for months even though the solution chosen causes death. In some cases fishes at the beginning tend to avoid the modified water, but soon, usually after a brief contact with the solution, begin to turn back from the pure water, having very quickly formed a preference or "habit" which keeps them in the poisonous solution".

These results are of the highest importance to the pollution question as fish entering water which is polluted by one of the above named compounds as a rule will turn back to the polluted water when pure water is encountered. The tendency to enter rather than to avoid portions of streams, which contain fatal contaminations, makes the loss of fish much greater than it would otherwise be.

Wells (1918) investigated the toxicity of carbon dioxide and carbon monoxide. Both gases are present in the waste waters of illuminating gas works and other industries. His investigations have shown, that both of the gases are poisonous to fresh-water fishes even when present in the water in relatively small proportions, but the monoxide proved to be by far the more deadly of the two.

"Carbon dioxide is present normally in the natural habitats of practically all fresh-water organisms, but its toxicity does not manifest itself unless it occurs in concentrations which are high as compared with lethal concentrations of carbon monoxide. At a concentration of 10 c.c. per litre, carbon dioxide will quickly prove fatal to the more sensitive fishes; and it is doubtful if there are any freshwater fishes that could continue to live in water where the carbon dioxide content averaged as high as 6 c.c. per litre throughout the year" (ibid. p. 557).

Carbon monoxide is a well known poisonous gas. The poisonous effects of illuminating gas are largely due to the comparatively large per cent. of carbon monoxide which it contains. As is the case with carbon dioxide carbon monoxide proved to be toxic in the concentration which would result from the introduction of wastes from gas works into ordinary water.

The following table from Wells' paper (p. 562) shows the relative resistance of several fishes to different concentrations of carbon monoxide. The concentration of the CO solution which flowed through the experimental bottles is expressed in c.c. per litre.

Species of fish	Weight of fish in grams	CO 1.2 c. c. per litre	CO 3.8 c. c. per litre	CO 6 c. c. per litre	CO 11.7 c. c. per litre
Moxostoma aureolum (Red-horse)	10—15			28 min.	10 min.
Notropis blennius (Straw-colored minnow)	2—4	1 hr.	45 min.	28 min.	
Pimephales notatus (Blunt-nosed minnow)	1—1.5	1 hr. 55 min.	1 hr. 20 min.		
Lepomis humilis (Orange-spotted sunfish)	2—6	5 hr. 40 min.	4 hr. 5 min.	1 hr. 5 min.	45 min.
Lepomis cyanellus (Green sunfish)	2—4	6 hr. 10 min.	5 hr. 25 min.	5 hr. 51 min.	4 hr. 5 min.
Ameiurus melas (Black bullhead)	20.5				9 hr. 55 min.

This table shows the high toxicity of water which contains even small quantities of CO in solution. Stronger solutions are proportionately more deadly. Earlier experiments (WELLS 1913) show "that a concentration of from 75—100 c.c. per litre of carbon dioxide is required to equal the killing effectiveness of 1 c.c. per litre of carbon monoxide".

Fishes are very sensitive to small changes in the carbon dioxide content of the water and tend to avoid detrimental concentrations of this gas by turning back very definitely from them. On the other hand they do not appear to detect the presence of carbon monoxide in the water and will swim into concentrations of this gas that kills them in a few minutes. In general the resistance of fishes corresponds with the environment in which they are found: the more resistant species live in ponds and shallow lakes, the least resistant fishes occur in swift streams and in cold, deep lakes.

STEINMANN and SURBECK (1920) however, who experimented with several species of salmonids, (*Trutta fario*, *Salmo irideus* and *salvelinus*, *Thymallus thymallus*) and Cyprinoids (*Phoxinus laevis*, *Alburnus bipunctatus*, *Gobio fluviatilis* a. o.), did not find in any of their experiments a marked difference in power of resistance between these fishes.

They studied the toxicity of various trade-wastes and mixtures of coal tar-products and of some of their more important constituents. In summarizing their results they give a review of the relative toxicity of the compounds studied, which is on the whole in close agreement with SHELFORD's figures. Instead of mentioning, however, the lethal doses they determined the limit of noxiousness ("Schädlichkeitsgrenze"), that is to say, the maximum quantity of a given poison, which is just harmless. So they found as "Schädlichkeitsgrenze" for:

Naphthalene	1 : 700.000—800.000
Phenol	1 : 250.000—300.000
Benzene	1 : 200.000
Toluene	1 : 200.000
Xylene	1 : 100.000
Cresolsaponate	1 : 100.000
Carbolineum	1 : 100.000
Benzine	1 : 25.000
Pyridine	1 : 10.000 ±

Naphthalene proved to be by far the most toxic, pyridine the least (cf. also table p. 26—27); as to the relative toxicity of the other hydrocarbons these authors found the consecutive order to be somewhat different, but they all range amongst the very poisonous compounds.

Steinmann and Surbeck (ibid. p. 90) draw special attention to their results in connection with the remarkable resistance of salmonid fry to some of the above named poisons. In older papers it was often stated, that in the case of water poisoning the pollution in the first place was injurious to "the tiny fry". In the case of tar compounds at least this view proved to be incorrect, as the fry of trout and char (*S. salvelinus*) could live for hours in solutions containing phenol, xylene and toluene of so strong a concentration, that they killed adult trout in a few minutes. These results are of importance in estimating the damage caused to fisheries by waste waters containing any of these compounds.

In a later paper (Steinmann and Surbeck 1922) the authors report upon their experiments with nicotine and some organic acids (oxalic acid, acetic acid, butyric acid, lactic acid and tannic acid). Nicotine is present in considerable quantities in the so-called Kentuckylye ("Kentucky-lauge") and although this liquor as a rule is used in the tobacco factories for etching purposes or sold as a means of combating plant-diseases, it has caused locally considerable damage to fisheries. The authors found that nicotine was a very serious poison for several fishes and that the limit of noxiousness was about 1 : 200,000.

The above named acids are usually present in trade wastes only in very small quantities, so that they are as a rule harmless, but they may be dangerous in very small waters. Moreover some of these acids are formed by the fermentation of organic bodies in polluted water; so the knowledge of their toxicity is not without interest.

In connection with the limit of noxiousness the authors found for:—

oxalic acid	1 : 50.000
acetic acid	1 : 20.000 (rainbow trout)
butyric acid	1 : 10.000
lactic acid less than	1 : 10.000
tannic acid	1 : 5.000?

Lehmann (1925) carried out some new experiments showing the toxicity of potassium cyanide present in solutions which are used in galvanoplastic works and sometimes produce a very serious mortality among fish. See also Hasenbäumer (1906).

A valuable contribution to our knowledge of the injurious effect of phenols is quite recently given by Holzinger (1927) in connection with a case of carp being killed in a fishpond by the effluent of a coke oven ("Kokerei"). He is of opinion, that in determining the toxicity of such effluents it is sufficient to measure the actual quantity of phenol, this being the chief noxious constituent and the only one that can easily be measured by chemical analysis. He found that carp (and also pike) will die even in such weak solutions as 5 per million.

2. Indirect influence of polluting agents upon fishes

The polluting substances which are to be dealt with in this paragraph have in common, that they affect the "milieu" in which fishes are living and in doing so act indirectly upon them. Such substances may either spoil the water and render it unfit for fish to live in or kill other animals and plants upon which the fish usually feed. In both cases fish will as a rule try to escape from the polluted zones and find others, where conditions of life are more favourable. In rivers therefore both kinds of pollution are on the whole less noxious than that mentioned in the foregoing paragraph, although in some cases, especially in smaller rivers, they have caused and still cause a considerable amount of damage.

In the first place must be mentioned all those polluting organic matters, which in consequence of their putrescibility decrease the quantity of dissolved oxygen of the water to such a degree that fish can no longer live in it. Among these are domestic sewages (vide chap. I) which may or may not contain trade refuse and trade wastes from several sources as: paper manufacture (Lundbeck, 1926); beet-sugar factories (Baudron, 1893; Marsson und Schiemenz, 1901; Schiemenz, 1902; Wundsch, 1920; River Pollution and Fisheries, 1926); starch-factories (Cronheim und Schiemenz, 1902; Fischer, 1901; Schiemenz, 1902, 1903; Hofer, 1903); dairies (River Pollution and Fisheries, 1926) and breweries, refuse from fellmongers' yards, abattoirs, tanneries, flax-retting (Johanson, 1882; Reichardt, 1883; Lehmann, 1923; Kisker und Lehmann, 1926) etc.

The consumption of oxygen in the "Vorfluter" may lead to a deficit which generally causes asphyxia in fish and it is only by the self-purification of the water, that normal conditions can be restored. Moreover the compounds of sulphuretted hydrogen and ammonia which are formed during the mineralizing process of the organic matters, act positively as poisons (see paragraph 1). Finally it seems probable that in most of these wastes specific poisons may arise during the decomposition of albuminous matters, such as cadaverine, putrescine, indol, skatol,

trimethylamine a. o. ("Fäulnisgifte"). Their action upon fishes however is scarcely known for the present. (Wundsch 1926). Schiemenz (1902, 1903) observed that effluents from beet-sugar factories if sufficiently concentrated act directly as poisons upon fishes and ascribed their toxicity to the presence of saponine and sapotoxine.

Reichardt (1883) and quite recently Kisker and Lehmann (1926) carried out several experiments with water used for retting flax. The authors used retting water of different age and found that fish even in fairly weak solutions died very soon from lack of oxygen. Kisker und Lehmann's conclusions as to the noxiousness of flax-retting waters for fisheries are the following (ibid. p. 126):—

1) The consumption of oxygen in retting water is very appreciable and chiefly accounts for its being injurious to fisheries.
2) The dangerousness of a given retting water does not depend upon its age. Retting water which has been used for only one day is as a rule as dangerous as retting water, which has been on the flax for eight days.
3) The acids, which are present in retting water are weak organic acids. They showed no injurious effect on fish.
4) A positively poisonous effect of retting water upon fishes was not observed. It may be that such an effect would have occurred in stronger concentrations than have been employed for these experiments but this is immaterial to fishery-questions as solutions containing 15 per cent. of retting water and showing no poisoning phenomena are in themselves detrimental on account of their strong consumption of oxygen.

Although the decrease of oxygen by putrescible effluents under unfavourable circumstances may cause a very extensive and very striking mortality among fish, its effect upon fisheries is on the whole not so disastrous as the more or less permanent and less obvious extermination by polluting matters of aquatic animals and plants which serve as food for fish. Fishes may and often do escape death by moving away from the contaminated zones, but the animals and plants on which they feed and which are chiefly more or less sessile, can not escape and in the case of severe or chronic pollution are often destroyed over a wide range. By this the bionomical character of the water is changed and it becomes unfit for fishes or at least for several species of fish.

It is obvious that not only organic pollutions but all sorts of harmful effluents may in this way indirectly affect fish-life. The sensitiveness of lower animals differs widely but seems to be on the whole greater than that of fishes.

Changes in the hardness of water usually affects lower animals more than fishes. Important food animals such as *Gammarus* disappear when the water is too soft. On the other hand the number of insect larvae shows a remarkable decrease in hard waters.

It is further well known that the majority of our common aquatic plants and animals are adapted to water which is slightly alkaline. So even weak acids

can, without directly affecting the fishes, in the long run render bionomical circumstances unfavourable by cutting down the food supply, and a sudden local destruction of the lower fauna by a concentrated effluent may be disastrous not only by killing fish but also and still more by killing valuable animals such as worms, molluscs and crustacea. These can not immigrate so quickly from neighbouring waters as fishes and it takes therefore a long time before such a deserted area will be repopulated.

It must be observed, however, that certain animals, which live under stones or can hide themselves in a muddy bottom are fairly well protected against all kinds of pollution. Others even thrive best in water polluted by sewage.

Special researches into the power of resistance of invertebrates to polluting substances are still rather scanty.

Hein (1909) stated that to coal-tar solutions invertebrates on the whole were much more resistant than fishes. I quote the following figures from his table IV (ibid. p. 110) showing the time during which various invertebrate species could live in a 1 : 10,000 solution of coal-tar.

Copepods	11—12 hours
Daphnoids	11—12 —
Ostracods	10.5-12 —
Gammarus	12—13 —
Asellus	12—13 —
Libellula young larvae	18—20 —
Culicidae larvae and nymphs	after 80 hours still alive
Planorbis marginatus	60 hours
Limnaea auricularia	63 —
Limnaea stagnalis	67 —

Thienemann (1911, see paragraph 1) observed that *Tendipes*, *Limnaea*, *Gammarus* and *Planaria gonocephala* were less resistant than *Asellus*.

Haempel (1915) determined the toxic influence of sulphuric acid on lower animals and found the following doses to be positively lethal for:—

Gammarus pulex	20 parts per million
Cloeon dipterum	40 — - —
Rotifer vulgaris	60 — - —
Cyclops spec.	60 — - —
Infusoria div. spec.	40—50— - —
Tubifex tubifex	80 — - —
Asellus aquaticus	100 — - —

Von Alten's (1915) results show that waste water of potassium salt works ("Kaliwerke") are not injurious to lower plants, especially not to Diatoms.

Steinmann und Surbeck (1918) examined the sensitiveness of *Gammarus*,

Baetis and *Ephemerella* to ammonia. It acted as a poison and killed *Baetis* in a solution of 1 : 10,000 in 6 minutes, *Ephemerella* in 35 and *Gammarus* in 15 minutes.

Wilhelmi (1922) studied the influence of chlorine.

Krämer (1924) published two interesting papers on the influence of iron-work waste waters upon the invertebrate fauna and flora of small rivers. These waters are acid and contain considerable quantities of dissolved iron hydroxide, which is partly precipitated as the water gets more alkaline. The colloidal iron particles cover plants so that they are unable to assimilate and consequently die. This occurs also with sensitive animals like molluscs and insect larvae. On the other hand some animals such as *Asellus* and various species of Oligochaetae, which usually live on bottom-material (detritus) get iron in their bodies in such quantities that it disturbs their vital functions, chiefly slackening growth.

Schiemenz (1925) in a recent paper writes upon the influence of the waste waters from salt deposits ("Kaliwerke") upon lower animals and fishes in the river Leine. His conclusion is that the effluents which at present under normal conditions reach the river are not injurious to them.

In addition to killing food animals and plants and dislodging the fishes polluting effluents are often detrimental to fisheries by depositing suspended matter in water so as to make it shallow and unfit as a habitat for fish or at least for certain species of fishes. This may occur in stagnant waters or in dead curves of rivers, where matters are precipitated which only slowly decompose, such as refuse of paper-manufactories and sawdust.

The latter has caused in former years a considerable amount of trouble in some Norwegian rivers. Landmark (1881) pointed out, that sawdust gradually sinks to the bottom and thus fills the very place, where the fish eggs (more especially salmon eggs) are to hatch, with impure and injurious matter. He also mentions a case, where fishing places were so completely filled with heaps of sawdust as to make the hauling in of the nets very difficult or even impossible[1]).

Knight's (1904) experiments[2]) showed that the extract from sawdust contains poisonous substances, killing adult fish, eggs and larvae. The source of the poison given off by sawdust is undoubtedly to be found in the contents of the wood cell. His chief conclusions (ibid. p. 465) are the following:—

1) Strong sawdust solutions, such as occur at the bottom of an aquarium, poison adult fish and fish fry, through the agency of compounds dissolved out of the wood cells.

[1]) In some countries (Sweden, Finland) the rafting of timber on rivers has caused considerable trouble by polluting the water with fibres and other particles of bark. (Trybom, 1903; Järvi, 1917).

[2]) This author gives a valuable historical account of the "sawdust-question" up to the year 1900.

2) The overlying water in such an aquarium does not at first kill fish. After about a week it does so, but solely through suffocation, the dissolved oxygen having all been used up.

3) Bacteria multiply enormously throughout all parts of such an aquarium, and through oxidation change poisonous extracts into harmless compounds. Mosquito larvae live on the bacteria. No doubt, in natural pools, other aquatic insect larvae live on bacteria also.

4) Subsequent aëration and sedimentation of sawdust water purify it, so that fish can live in it without injury.

5) Since adult fish and black bass fry both refused to be driven into pine extracts in the bottom of an aquarium after they had experienced its poisonous effects, we may infer that fish would desert a river much polluted with sawdust by going down stream and into tributaries to escape from the disagreeable influence of sawdust extracts.

6) No stream can be pronounced off hand to be poisoned by sawdust. Each stream must be studied by itself and the varying conditions must be thoroughly understood before a judgment can be pronounced. The chief things to be considered are the quantity of sawdust, and the volume of water into which the sawdust is discharged. Subordinate conditions are the rapidity or sluggishness of the stream, the amount of sunlight or shade, and the character of the water, whether from agricultural lands or from primitive forests.

How quickly conditions of existence in a river may be spoiled by pollution is shown by RICHARDSON (1921), who gives a very interesting account of the changes that have occurred both in the composition and abundance of the small bottom invertebrate fauna of the Illinois River system between Chillicothe and Browning since 1913—1915, these points being respectively 146.5 and 229.5 miles below the mouth of the Chicago River. The results are based upon hauls made in the summer 1920 with PETERSEN'S quantitative bottom-sampler and clearly show a conspicuous deterioration in the conditions of existence of the aquatic fauna caused by increasing pollution. The changes include: "sweeping reductions in numbers and poundage of the still surviving groups of small bottom animals, total obliteration of numerous families and species, and, in the range covered above Havana, the intrusion in large numbers of new pollutional or tolerant forms. If, as is approximately correct, we assume that Chillicothe marked about the upper limit of wholesome conditions in the bottom muds in 1915, then the added river mileage that is shown to have been more or less seriously damaged since that time figures out at not less than eighty and represents an average southward encroachment of pollution amounting to fully sixteen miles per year for each year of the five". (ibid. p. 33).

In 1919 a remarkable improvement of conditions prevailing in public waters

has been observed in Belgium as a result of the shutting down of the industries during war. (cf. Circulaire ministérielle, Ministère d'Agriculture, du 18. Novembre 1919).

3. Influence of pollution upon fisheries

It follows from the foregoing, that fisheries may be affected by pollution in different ways.

Mortality among fish either due to poisons or due to the dissolved oxygen of the water being decreased is of frequent occurrence. In most cases the wholesale killing of a great number of fishes ("Fischsterben") is caused by the sudden influx of waste waters containing poison. The majority of such catastrophes, records of which are to be found now and then in every fishing gazette, occur in small rivers and chiefly in the dry season, the quantity of water being then at its minimum. The dilution of the fatal effluent is consequently minimal and since fishes, as we have seen, are in most cases unable to move away from the poisoning liquor, this form of pollution is often very ruinous to fisheries.

Lack of oxygen brought about by putrescent wastes also often causes a severe mortality among fishes. But as a rule the effect of this kind of pollution on fishes is not so deleterious, as they usually move away from the contaminated zones and find other places, where they can live[1]). On the other hand a continuous discharge of such effluents may in the long run prove to be very noxious to fisheries, as it may cause a depopulation of the water or at least the extermination of certain valuable species (salmon, trout).

Moreover we have seen that either by poisonous or by putrescent matters the food supply of fish may be seriously affected, so that over wide areas the conditions of life become unfavourable and the fish disappear.

In any of these cases the stock of fish is directly or indirectly affected and the pollution does damage to the fisheries by rendering the water poor and diminishing the catch. This form of damage is especially prevalent in more or less stagnant waters, i.e. in some parts of Holland, where the salutary self-purification of running waters is lacking. It should be kept in mind that for the sake of the fisheries under these circumstances putrescible effluents should be treated in order to diminish their putrescibility to the utmost before they are allowed to reach the water, whereas the discharging of effluents containing poison should be strictly prohibited.

Pollution can, however, be troublesome to fisheries in still another way, viz. by encumbering the actual fishing. This occurs chiefly in such cases, where the waste water contains non-putrescible flocks or fibres or slimy substances which settle on the nets and choke up the meshes, so that their catching power is seriously

[1]) This does not of course apply to fishes, which are caught in nets or kept in caufs and which will suffer most from any kind of pollution.

diminished. This kind of obstruction has been caused also by the presence of typical polysaprobe fungi such as *Sphaerotilus* and *Leptomitus* (Lundbeck 1926).

It is generally admitted, that fish acquire a bad flavour in water, which has been contaminated by wastes containing mineral oils or carbolineum. But a similar bad flavour has been observed in cases, where a contamination with such substances is at least very doubtful. As a rule the taste or flavour is compared with that of phenol (carbolic acid) but it has very often a close resemblance with the smell of iodoform and probably is brought about by lower plants (*Cyanophyceae*, *Flagellates*) which have served as food for the fishes.

Finally I may mention here, that some authors (Volk, Schiemenz, Hentschel) feel inclined to look upon the discharging of town sewages into large rivers as rather advantageous from the standpoint of fisheries. It is shown by Hentschel (1917), that even the enormous quantities of sewage, which are discharged by Hamburg-Altona into the river Elbe do not seriously interfere with its powers of self-purification. Volk (1910) is of opinion that the large quantities of organic putrescible matters, which are carried along with the effluents and which after being mineralized yield various soluble nitrogenous compounds, act as fertilizers, in the same way as manure does on fields, by stimulating the growth of the phytoplankton, chiefly Diatoms. These Diatoms serve as food for pelagic Crustacea, chiefly Copepods (*Eurytemora affinis!*), on which again several species of fish feed either as larvae or young-fishes or during their whole life. So the abundance of fish in the Elbe estuary is said to be partly due to the influence of pollution.

In summarizing the foregoing paragraphs we may state:

Whether river pollution will be injurious to fisheries depends on:—

a) The relation between the volume of the effluents and the capacity of the river ("Vorfluter"). Factories producing large quantities of waste waters should not be allowed to discharge their effluents into small rivers (or stagnant waters), without previously purifying them. The degree of purity which should be aimed at largely depends on local circumstances.

b) The nature of the pollution effluent. The discharge of such substances which act directly as poisons upon fishes or lower animals and plants should be prohibited by all means. Organic effluents should be treated by one of the methods described in chapter I in order to reduce their putrescibility to a minimum. The tolerable degree of impurity again depends on local circumstances and must be determined in every case on its own merits. As far as experience goes, town sewages if properly treated do not cause any serious damage to fisheries, and even may to a certain extent prove salutary in large rivers.

c) The nature of the water into which the effluents are discharged. Water which contains a certain amount of lime (hard water) will for instance stand an influx of acid wastes better than water with a low percentage of lime (soft water).

d) The kind of fishes occurring in the waters which are subject to pollution. It has been shown that some important food-fishes, such as salmon, trout, pike and perch are generally more sensitive to pollutions than others such as carp, tench, eel.

CHAPTER IV

Regulations to prevent pollution

Up to about the middle of the 19th century practically all sewage effluents and all trade waste waters were discharged without let or hindrance into the nearest rivers. In England local authorities were sometimes even required to discharge their crude sewage into rivers. (Towns Improvement Clauses Act, 1847.) As a natural sequence of events many rivers in thickly populated districts or industrial centres became polluted and complaints followed. The attention of authorities was drawn to this fresh nuisance and nowadays in the majority of our civilised countries laws and other measures are in force to prevent the damage caused by the pollution of public waters.

It lies beyond the scope of this report to deal fully with all existing laws, acts and other regulations, connected with river pollution. So I may confine myself to a summary review of the principal regulations which are in force in those countries where river pollution nowadays is more or less successfully combated.

Belgium. In cases of pollution of navigable waters ("cours d'eau navigables ou flottables") proceedings may be taken under article 91 of the "Réglement général des voies navigables administrées par l'État" (1889) prohibiting the alteration of rivers by the discharge of substances into the bed. The act of May 7th 1877 with supplementary local regulations contains similar provisions for the non-navigable waters. Other provisions are to be found in the "Arrêté royal du 29. Janvier 1863 portant réglementation générale de la police des établissements dangereux, insalubres ou incommodes." In article 6 it is enacted, that the authorisations for the establishing of manufactories "sont subordonnées aux réserves et conditions qui sont jugées nécessaires dans l'intérêt de la sûreté, de la salubrité et de la commodité publiques."

Denmark. The prevention of water pollution is entrusted to the Board of Fisheries ("Fiskeridirektoratet") and the Board of Health ("Sundhedsstyrelsen"). The Danish Freshwater Fisheries Act, 1917 and the Seafisheries Act, 1917 contain each a clause (§ 13 and § 23 respectively) dealing with pollution. Other provisions are to be found in the local regulations as to health ("de kommunale Sundhedsvedtægter").

England. An Act dealing expressly with the pollution of rivers by sewage and trade refuse, Rivers Pollution Prevention Act, was passed by the Govern-

ment in the year 1876 and is still in force. Under this Act it is an offence to put any solid matter, sewage or polluting matter from any manufacturing process into any stream so as to cause pollution. Proceedings under this act are brought before a County Court. The act of 1888 provided for the combination of adjoining County Authorities in the administration of this act, so that one Joint Committee could be formed to deal with the whole course of a river. Under this provision three Joint Committees have been formed: the Mersey and Irwell Joint Committee (Manchester), the Ribble Joint Committee (Preston) and the West Riding River Board (Wakefield). Two other authorities which exercise jurisdiction as regards pollution practically over the whole area of a watershed are the Thames Conservancy Board and the Lee Conservancy Board. Lastly the River Pollution Act was slightly amended by a short act of 1893.

Very important work has been done by the Royal Commission on Sewage Disposal appointed in 1898, whose reports were published from 1901—1915. Until lately matters relating to river pollution were dealt with by the Local Government Board (now the Ministry of Health).

The new Salmon and Freshwater Fisheries Act, 1923 deals also with pollution. One section (8) is devoted to the protection of waters containing fish from poisonous matter and trade effluents, another (55) deals with the power to prevent the pollution of water given to local fishery boards and by a third (59) certain powers are granted to fishery boards to make bye-laws, i.e. for regulating the discharge of polluting effluents.

Finland. The Finnish legislation relating to water (Act of July 22nd 1902) prohibits river pollution only in general terms. Until lately these provisions proved to be fairly adequate but nowadays they are not longer satisfactory owing to the development of new manufactures. Local authorities and finally the Court have to decide to what extent and on what conditions pollutions are to be looked upon as tolerable.

France. River pollution comes within the jurisdiction of the "Conseil Supérieur d'Hygiène Public". A bill entitled "Projet de loi régulatif aux mesures à prendre contre la pollution et en vue de la conservation des eaux" was brought in December 24th, 1910, but until now it has not been passed by the Government. Local authorities (the Prefects) are entitled to issue such instructions as they may deem necessary in special cases.

Germany. At yet there is no law against river pollution which applies to the whole Republic. Provisions are made from time to time by the Board of Health ("Reichsgesundheitsrat") and the Bureau of Health ("Gesundheitsamt"). For the rest regulations are to be made by the Governments of the individual

States. This arrangement very naturally may give rise to difficulties if the same river flows through different States, which is very often the case. Acts against water pollution were passed in Hesse (1887), Baden (1899), Würtemberg (1900), Hamburg (1905), Bavaria (1907), Saxony (1909) and Prussia (1913). Here the "Preussische Anstalt für Wasser-, Boden- und Lufthygiene" acts as an advisory body and is the place, where all researches on water and water pollution are centralized. In the more important industrial districts Joint Committees ("Wassergenossenschaften") are formed, of which the well known "Emschergenossenschaft" is the oldest (1904).

Holland. Pollution of public waters may be prohibited by the Town Councils in virtue of certain clauses which are contained in the Act to prevent Nuisance by Factories and Workshops ("Hinderwet" 1875). A bill supplementary to this Act was brought in in the year 1912 and a new bill entitled "Sewers Act" ("Riolenwet") in 1913. These bills however were not passed and were again brought in in the year 1922. They are still under consideration. Meanwhile a central Institute for the Purification of Sewage and Trade Wastes ("Rijksinstituut voor de Zuivering van Afvalwater") has been founded in the year 1920. This is a research institution and acts as an advisory body.[1])

Ireland. In cases of pollution injurious to fish proceedings are usually taken under section 80 of the Fisheries (Ireland) Act 1842. Offences against this section may be brought before a court of summary jurisdiction on the complaint of any person. In practice such complaints would be made by the Boards of Conservators of Fisheries or by the Civic Guards (police).

This section is sufficient to cover all cases of pollution which might be injurious to fish.

Under the Rivers Pollution Act 1876 it is an offence to put any solid matter, sewage, or polluting matter from any manufacturing process into any stream so as to cause pollution. Proceedings under this Act may be taken by any Sanitary Authority or any person aggrieved by the commission of the offence, except in the case of manufacturing and mining pollution when proceedings can only be taken by the Sanitary Authority with the consent of the Minister for Local Government and Public Health who may not give his consent unless he is satisfied that no material injury will be inflicted by such proceedings on the interests of the industry which gives rise to the pollution. Any rights or powers existing by law or custom at the time of the passing of the Act are exempted from its provisions, and two months' notice must be given to the offender. Proceedings under this Act are brought before a County Court. In practice this Act seems to be seldom if ever brought into operation.

[1]) Recently (May 1927) the Institute has been reorganised; it is now directly under the Minister of Labour, Trade and Industry.

Norway. The "Use of Waters Act" (July 1st 1887) contains five paragraphs (20—24) dealing with River-Pollution. Owners of manufactories are not allowed to discharge wastes either in fluid or in solid form into any public water, if thereby damage is caused to other persons, who are interested in the water. It is to be decided by the King or by the Board of Hydraulics and Electricity ("Hovedstyret for Vassdrags- og Elektrisitetsvesenet"), if and in how far measures to prevent pollution are to be taken. Offences against this section may be brought before a police magistrate. Moreover proceedings may be taken under § 12 of the "Nuisance to Neighbours Preventing Act" (May 27th 1887). At the present time measures against river-pollution in Norway are under revision.

Scotland. The Public Health (Scotland) Act of 1897 contains three sets of provisions dealing with the subject. In section 16, if the pollution of a watercourse amounts to a nuisance — a term clearly capable of much dispute — or is injurious or dangerous to public health, the local authority is required to take proceedings. By section 116, the local authority is required in the same way to take action if distilleries, manufactories or works of other kinds discharge into any stream material dangerous to public health. And by section 127, a heavy penalty is instituted against any manufacturers who pollute streams used for domestic purposes, the reference being specially directed against the introduction of wastes from gas, naphtha, vitriol, paraffin and dye stuffs. The first section referred to has eleven sub-sections.

The provisions are not very applicable to fishery interests, and are not intended to be so, but none the less conscientious action by local authorities would do much to benefit the fisheries.

The Burgh Police Act of 1892 contains two provisions to prevent the throwing of rubbish into streams or on to the banks of streams, or the discharging of offensive matter into streams within a burgh, instead of into the sewers. The offence of depositing rubbish seems generally to be got over in country districts by tipping outside the burgh boundaries, and so far as the fisheries are concerned, it matters little whether offensive matter comes into a river through sewers or not, if the contents of the sewers are not purified in any way.

The Rivers Pollution Prevention Acts, 1876 and 1893, were designed expressly for the purpose described in their title.

The Act of 1876 has three sets of provisions dealing with pollution. Sections 3, 4 and 5 established as offences the discharge of sewage into streams, the discharge of manufacturing wastes, and the discharge of pit water respectively. In each case, however, there is the proviso that a person complained against shall not be deemed to have committed an offence if he shows to the satisfaction of the Court before whom he is tried "that he is using the best practicable and available means of rendering harmless" the discharge complained of. In addition, in clause 5, that referring to mines, an exception is made in respect of "water in the same condition as that in which it has been drained or raised from such mine." This last was exemplified very acutely some years ago, when water from a pit which had been closed down for some time was pumped into a small burn, a tributary of the river Girvan. The water contained such a high percentage of iron sulphate that a bright orange precipitate was immediately created in the burn, forming a thick crust on the bed of the stream, while the river Girvan from the mouth of the burn downwards ran in a thick yellow flood, and every fish in the river died. This water was in the same condition as when raised from the mine. The pumping continued for months till the pit was emptied, and several seasons elapsed before a moderate stock of salmon could be re-established.

With regard to the best practicable or available means of purification, or the

variant of the phrase "the best practiable and reasonably available means," it may be observed without fear of contradiction that great advances have been made in purification since 1876, but that even very moderate and easily available means are often conspicuous by their absence.

By section 12 a certificate may be granted by a qualified inspector showing that the means of purification employed "are the best or only practicable or available means under the circumstances of the particular case", and this in all proceedings will be held as conclusive evidence of the fact.

As an additional safeguard against undue interference with manufacturing and mining interests, section 6 enacts that proceedings shall only be taken at the instance of a Sanitary Authority with the consent of the Local Government Board (Board of Health). This was afterwards qualified by section 55 of the Local Government (Scotland) Act, 1889, which empowered County Councils to act in the same way and with the same powers as Sanitary Authorities. As members of County Councils are not infrequently concerned in the creation of pollutions, this clause has not proved of much use, while it may be said that the complications of procedure and the safeguards against interference with polluters have rendered the Rivers Pollution Prevention Acts of practically no use to those interested in the preservation of our fisheries.

In the Salmon Fisheries (Scotland) Act, 1862, there is another reference to pollutions, but it embodies the same sort of proviso as to "the best practicable means within a reasonable cost". This introduction of the element of cost is liable to be interpreted variously, and to mean in the main that any large cost cannot reasonably be contemplated. Modern purification plants cannot be erected without a fair amount of cost, and those interested in the fisheries are naturally inclined to the view that even a large cost, being the price of a pure river, is reasonable. Section 13 as amended by section 16 of the Salmon Fisheries (Scotland) Act, 1868 — the very latest Act — reads as follows: — "Every person who causes or knowingly permits to flow, or puts or knowingly permits to be put, into any river containing salmon, any liquid or solid matter poisonous or deleterious to salmon, to an extent injurious to any salmon fishery, shall be liable to the following penalties". The weak point here is the expression "to an extent injurious to any salmon fishery", a phrase which originally had reference to the discharge of sawdust, but which when the reference to sawdust was deleted, was left in as if by an accident of drafting.

Procedure here is at the instance of a clerk to a District Fishery Board, and in practice it has been found that to prove injury it is necessary to produce salmon found dead, and to prove that they have been killed by pollution. Proof of this nature is exceedingly difficult to obtain, and the unfortunate fact is that by the time adult fish have been killed by pollution an infinite amount of harm has already been done to fry and to the food of the fry, while the gravels forming the bed of the river may have been rendered quite unsuitable for salmon to spawn in.

Sweden. The authorities dealing with river pollution are the Medical Board, the Local Government Board and the Board of Agriculture with local officials. The law under which proceedings can be taken in cases of pollution is the Landowners' Rights over Water Act ("Om Jordägares Rätt över Vatten å hans Grund"), 1880. A project of a new act against air- and water-pollution is now in progress.

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